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Barriers to implement extensive green roof systems: A Hong Kong study

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ABSTRACT

Air pollution problems caused from the development of infrastructures are getting serious, in which air flow is reduced and heat is trapped among high-rise buildings. In order to mitigate these problems, various methods have been developed in previous studies. Extensive green roof has been identified as one of the most important means to mitigate these problems and implement sustainable development principles in the building features. Governments world-wide have been introducing various policies and regulations for promoting extensive green roof particularly for building projects. However, the existing buildings in many large cities such as Hong Kong display few extensive green roof features. Hong Kong is one of the most densely populated cities with many high-rise buildings. This paper examines the major barriers encountered in promoting extensive green roof systems for the existing buildings in Hong Kong. Case study approach is adopted to investigate how and why the barriers can hinder the implementation of extensive green roof features. Research results show that lack of promotion and incentives from governments and the increase maintenance cost are identified as the top barriers to the implementation. The paper concludes by providing further suggestions and actions that can help mitigate these existing barriers.

Contents

1. Introduction

Green roof systems are living vegetation installed on the roofs and could positively contribute to the mitigation of urban heat island and enhancement of building thermal and environmental performance [1–3]. Green roof system has been greatly promoted by the Hong Kong government since 2001. Recently, more projects have applied extensive green roofs in Hong Kong mainly in government buildings and public buildings such as schools. Although benefits can be achieved with the widespread market penetration of implementing green roofs, barriers to the applications remain [4].

It is suggested by many studies that green features in the development of construction projects provide opportunity for developers, contractors and policymakers looking to reduce negative environmental effects of projects development [5]. A wide range of green features, such as green roof technologies [6], waste management technologies [7], solar systems [8] and HVAC systems [9] were identified in previous studies. These green strategies aim to attain long-term building performance and sustainability, reduce building operational costs, preserve the health of building residents, and contribute to energy saving.

Previous studies have demonstrated that governments worldwide have been introducing various policies and regulations in promoting green roof technologies particularly for building

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projects. Germany is considered as the world leader in promoting green roof technologies [10,11], where over 10% of houses installed green roofs. Green roof applications are also common in other European countries such as France and Switzerland. In Portland, several incentive programs are launched to encourage construction of green roofs on buildings [12]. The city of Toronto has been promoting wider use of green roofs as a sustainable alternative to meet many of the urban environmental challenges [13]. In the United Kingdom, green roofs are used in built-up city areas where residents and workers often do not have access to gardens or local parks [14]. Nevertheless, the buildings constructed with green roof systems are often showcase buildings. In Hong Kong, the government introduces Joint Practice Note No. 1 (JPN1): Green and Innovative Buildings and Joint Practice Note No. 2 (JPN2): Second Package of Incentives to Promote Green and Innovative Buildings for the private developers in providing more green building features such as green roofs.

There are generally two types of green roof systems, which include intensive green roof system and extensive green roof system. Intensive green roof systems are characterized by deep (>6 in.) growing media, opportunities for a diverse plant palate on the rooftop, high cost and maintenance requirements [15]. The "intensive" green roofs are being replaced by "extensive" green roofs, which have a much thinner, lighter media (thus fewer structural requirements), and different plants choices [16]. The green roofs can provide many environmental benefits, which include improving ambient air quality [17], decreasing surface temperature of roof membrane and energy use in the buildings [2], retaining storm water for small storm events [18], and increasing biodiversity and habitat in urban areas largely lack of such space [19,20]. On the other hand, extensive green roofs are suitable for lightweight buildings; the plants adopted are species of sedum, shrubs and bushes that need low maintenance and can be self-generative. Usually, cost is lower than semi-intensive or intensive green roofs [21].

However, it appears that there is limited effectiveness of the application of extensive green roofs in the existing buildings practice. Little studies have been given to examining the major barriers that hinder the green roof applications. This paper therefore aims to investigate the major barriers for using green roof in existing buildings in Hong Kong. The identification of the major barriers is verified by using three case studies in the practice of adopting extensive green roofs. The paper concludes by proposing several proactive suggestions on overcoming the existing barriers to help promote the implementation of extensive green roof systems.

2. Research methodologies

The research data in the study was collected using a combination of literature review, existing research reports, questionnaires survey, case-study and structured face-to-face interviews with housing project managers. The questionnaire survey was conducted to examine the applicability of green technologies in housing projects and its barriers. Case studies were then employed to demonstrate that whether green building elements can provide competitive advantages for developers in housing project development.

From the review on previous studies [10,22–25], 11 barriers have been identified when implementing extensive green roof systems for the existing buildings (see Table 1). To understand the significance of the barriers that affect the implementation of extensive green roof systems to the existing buildings in Hong Kong, a constructive questionnaire surveys has been conducted in the local construction industry. Dillman (1978) suggested that both mailed questionnaires and site questionnaire survey were effective methods to obtain the maximum possible responses [26]. The target groups of the questionnaire include academia, professionals from private building companies such as contractors and building consultants and government departments relates to building such as architects, surveyors, engineers and general public. This can allow different views from the target groups and compare among their views.

The survey was carried out from June to September 2009 through email and by hand. A total of 672 questionnaires were sent out to different group of respondents and 232 of them returned the completed questionnaires, with the response rate of about 34.52%. Likert scale is used in the questionnaire to help respondents present their opinions. The Likert scale is commonly used for rating the relative significance of individual factors through examining experts' opinion [27,28]. The respondents were invited to give their opinion on the relative significance of each barrier to hinder the implementation of extensive green roof systems for the existing buildings in Hong Kong. The respondents were invited to judge the significance degree of each listed barrier, with grading "1" as strongly disagree, "2" being disagree, "3" being neutral, "4" being agree and "5" as strongly agree.

Relative Importance Index and Spearman's Rank Correlation Test among respondents were employed in the data analysis. According to the survey data, the relative significance of each of the barriers encountered in the implementation of extensive green roof system is calculated by Relative Importance Index, which can be calculated by the following formula.

$$\text{Relative importance index (RII)} = \frac{\Sigma w}{AN}, (0 \leq RII \leq 1) \quad (1)$$

where w denotes 'the sum of individual scores given to each factor by the respondents'; A means 'the highest score for each factor (i.e. 5 in this case)' and N denotes 'total number of responses concerning the factor'.

Spearman's Rank Correlation Test is used to measure the level of agreement among different group of respondents. The opinion of different group of respondents is analyzed by mean score. Different group of respondents will be compared to find out any different views among them. The following formula is used for the calculation.

$$\text{Spearman's rank correlation coefficient} (r_s) = 1 - \frac{6\Sigma^{d^2}}{N(N^2 - 1)} \quad (2)$$

where d denotes 'difference in rank of two parties for same factor' and N equals 'total number of responses concerning that factor'. And $r_s = 0'$ means "No correlation"; $r_s = +1'$ means "Perfect positive correlation"; $r_s = -1'$ denotes "Perfect negative correlation".

Correlation is investigated to show the relationship between groups. There is an assumption that Ho is equal to no significant correlation on the rankings between two groups when the significant level in each group is lower than 0.05.

Three case studies: (1) New Police Headquarters, Kowloon City; (2) New Electrical and Mechanical Services Department Headquarters, Wan Chai; and (3) Primary School at Sze Mei St, Ho Man Tin, implemented extensive green roof systems are also conducted to highlight the barriers encountered and suggestions to help promote the implementation of extensive green roof systems in Hong Kong. The interview discussions in each case study lasted around one hour, involving full discussion between this research team and the project managers who have been working on the projects.

3. Result and discussion

Table 2 summarizes the results of the relative importance index for the barriers in the implementation of extensive green roof systems for the existing buildings in Hong Kong. Nearly 80% of the respondents agree or strongly agree that "Lack of promotion

Table 1
Summary of optional barriers for applying extensive green roof systems for existing buildings in Hong Kong.

Code	Barriers	Key references
B_1	Increase of maintenance cost	Ngan [10]; Steven and Chris [23]
B_2	Increase of design and construction cost	Ngan [10]
B_3	Lack of incentive from the government towards developers	Getter and Rowe [22]
B_4	Lack of incentive from the government towards owners of the existing buildings	Steven and Chris [23]; Getter and Rowe [22]
B_5	Technical difficulty during the design and construction process	Steven and Chris [23]; Getter and Rowe [22]
B_6	The old age of existing building	Townshend [24]
B_7	The weak affordability of extensive roof to withstand wind load	Steven and Chris [23]; Townshend [24]
B_8	Weak structural loading for applying extensive green roof system	Townshend [24]
B_9	Poor utilities arrangement	Townshend [24]
B_{10}	Lack of awareness on extensive green roof system in public and private sectors	Hui [21]
B_{11}	Lack of promotion from the government and social communities among the public and private sectors	Townshend [24]

from the governmentand social communities among the public and private sectors" is the most significant barrier with a relative importance index of about 0.814. There is an urgent need for culture cultivation of using extensive green roof systems in the densely populated city, such as Hong Kong. Besides, even with sound energy efficiency standards for green roof systems, the commitment is undermined by the weak monitoring mechanisms in place and the insufficient legal enforcement. The compliance with employing extensive green roof systems in the existing buildings is very low due to the lack of financial support and professional experts, which cannot address the complex construction process and technique difficulties within the extensive green roof technologies. The phenomenon is echoed with the result that "Lack of incentive from the government towards the owners of the existing buildings" and "Increase of maintenance cost" being ranked as the second and third most significant barriers respectively for applying the extensive green roof systems in Hong Kong. These barriers can affect the development of green roof in many ways. For example, because of the lack of promotion from the government, little knowledge and awareness from the public and private sectors is received accordingly. On the other hand, once the extensive green roof system is adopted, regular maintenance is required. However, maintenance is a long-term process and continuous maintenance cost is required. Therefore, incentive from the government to the existing building owners is very important before the construction of extensive green roof systems. If the government introduces policies or mechanism to attract the use of extensive green roof with incentives provided to the existing building owners, other constraints can be reduced. With incentive measures, it is expected that extensive green roof systems can be developed in the existing buildings.

On the other hand, "Poor utilities arrangement" is identified as the least important barrier with a relative importance index of 0.720 from the survey results. Hong Kong has high rainfall in the summer season. There is a need for building effective drainage arrangement utilities in the extensive green roof systems to avoid flooding on roof and affecting the floor level below the extensive green roof. Irrigation and water supply should also be provided to the green system. Most of the building utilities in Hong Kong have been constructed before the construction of extensive green roofs [24]. In this context, the poor utilities arrangement for green roof systems of the existing buildings is not a major problem.

Tables 3 and 4 summarize the results of the Spearman's Rank Correlation Test between groups of respondents for the major barriers and comparison of the Spearman's Rank Correlation Coefficient (RCC) and its level of significance for the major barriers respectively.

From Table 4, special case is defined between "architecture vs. engineering" and "architecture vs. Academic" group of respondents, where Ho is rejected. In this context, there is no significant disagreement among the respondents in each group on the rankings of the major barriers to the applications of extensive green roof systems to the existing buildings in Hong Kong. However, RCC in "architecture vs. engineering" and "architecture vs. Academic" are higher than 0.05. This evidence concludes that there is significant disagreement for the two groups of respondents.

Table 2
Ranking of the major barriers for in application of extensive green roof system to existing buildings in Hong Kong (all the respondents).

Major barriers	Percentage of respondents scoring			Relative importance index	Rank
	≥ 4	3	≤ 2		
B_{11} – Lack of promotion from the government and social communities among the public and private sectors	77.2	15.5	5.2	0.814	1
B_4 – Lack of incentive from the government towards the owners of the existing buildings	72.8	19.0	4.3	0.799	2
B_1 – Increase of maintenance cost	75.4	19.0	3.0	0.788	3
B_{10} – Lack of awareness on extensive green roof system in public and private sectors	67.7	21.6	4.3	0.783	4
B_6 – The old age of existing building	73.3	18.5	4.7	0.777	5
B_5 – Technical difficulty during the design and construction process	66.4	25.9	4.3	0.774	6
B_8 – Weak structural loading for applying extensive green roof system	66.4	23.7	7.8	0.753	7
B_2 – Increase of design and construction cost	62.1	29.7	5.2	0.752	8
B_3 – Lack of incentive from the government towards developers	60.8	26.3	9.9	0.747	9
B_7 – The weak affordability of extensive roof to withstand wind load	65.1	24.6	7.8	0.742	10
B_9 – Poor utilities arrangement	58.6	26.3	12.9	0.720	11

Table 3
Spearman's Rank Correlation Test between groups of respondents for the major barriers.

	Architecture	Surveying	Engineering	Academic	Others
Architectural	1.000	0.534*	0.501	0.496	0.673**
Surveying	0.534*	1.000	0.919**	0.915**	0.947**
Engineering	0.501	0.919**	1.000	0.852**	0.837**
Academic	0.496	0.915**	0.852**	1.000	0.912**
Others	0.673**	0.947**	0.837**	0.912**	1.000

Note: **Correlation is significant at the 0.01 level (2-tailed).

Table 4
Comparison of the Spearman's Rank Correlation Coefficient and its level of significance for the major barriers.

Comparison	r_s	Significance	Conclusion
Architecture ranking vs Surveying ranking	0.534	0.049	Accept Ho
Architecture ranking vs Engineering ranking	0.501	0.068	Reject Ho
Architecture ranking vs Academic ranking	0.496	0.071	Reject Ho
Architecture ranking vs other ranking	0.673	0.008	Accept Ho
Surveying ranking vs Engineering ranking	0.919	0.000	Accept Ho
Surveying ranking vs Academic ranking	0.915	0.000	Accept Ho
Surveying ranking vs Other ranking	0.947	0.000	Accept Ho
Engineering ranking vs Academic ranking	0.852	0.000	Accept Ho
Engineering ranking vs other ranking	0.837	0.000	Accept Ho
Academic ranking vs other ranking	0.912	0.000	Accept Ho

Note: where Ho = No significant correlation on the rankings between two groups.
Ha = Significant correlation on the rankings between two groups.

4. Case studies

Three case studies are selected for further investigation on the barriers to using green roof: (1) New Police Headquarters, Kowloon City (see Fig. 1); (2) New Electrical and Mechanical Services Department Headquarters, Wan Chai (see Fig. 2); and (3) Primary School at Sze Mei St, Ho Man Tin (see Fig. 3). The examinations on the case studies were conducted to show what barriers encountered when the extensive green roof system is implemented and suggestions to help promote the implementation.

Based on the discussions of the case studies, the major barriers against the use of extensive green roof in the three case studies were identified, which are presented and compared in Table 5. They are listed in the order of frequency of citation by the project team members. In the process of interviews, though no relationship should be inferred between frequency and importance of the barrier in hindering the extensive green roof systems. However, it is interesting to see which barriers appeared most regularly in the interviews and written sources.

Fig. 2. New Electrical and Mechanical Services Department Headquarters, Wan Chai (Case 2).

Fig. 1. New Police Headquarters, Kowloon City (Case 1).

Fig. 3. Primary School at Sze Mei St, Ho Man Tin (Case 3).

Table 5
The barriers encountered in the three case studies (refer Table 2).

	Plan and design	Construction	Operation and management
Case 1	B_{11}; B_4; B_{10}; B_5; B_2; B_9	B_1; B_5; B_2	B_1; B_{11}; B_9
Case 2	B_4; B_{11}; B_5; B_2; B_{10}	B_5; B_2	B_1; B_{11}
Case 3	B_4; B_{11}; B_5; B_{10}	B_5; B_9; B_2	B_9; B_1

The practices show that significant barriers exist in applying the extensive green roof systems in the whole construction processes, including plan and design, construction and operation and management stages. The results from the three case studies are echoed with the major barriers identified in the questionnaire survey (presented in Table 2), including 'Lack of promotion from the government and social communities among the public and private sectors', "lack of incentive from the government towards the owners of the existing buildings" and "increase in maintenance cost". It can be seen from Table 5, during the plan and design stage, "Lack of promotion from the government and social communities among the public and private sectors", "Lack of incentive from the government towards the owners of the existing buildings", "Increase of maintenance cost" and "Technical difficulty during the design and construction process" have been referred to in the three case studies, which indicates that the government promotion and incentives all play significant roles in the plan and design stages for the implementation of extensive green roof systems. While in the construction and Operation, and Management stages, "Increase of maintenance cost" and "Technical difficulty during the design and construction process" are appeared to be more important in the three case studies. This is due to the high construction and maintenance cost in producing green buildings. Life cycle cost which includes capital cost, recurrent cost and maintenance cost should be considered to assess the application of green buildings. Moreover, it is believed that green roof can retain for 40–50 years but conventional bare roof can only retain for 25 years [10].

5. Suggestions to promote the implementation of extensive green roof systems

According to the interview discussions from the three case studies, it is obvious that barriers occurred from the whole process of the green roof projects. First and foremost, the lack of promotion and incentives has become the top barrier. Until now, there is still lack of quantifiable data pertaining to the benefits that extensive green roofs can provide to the building owners, its occupants, and the communities [22]. And the citizens in Hong Kong has not yet cultivated the green living styles by employing extensive green systems on their building roofs. As the constraints for implementing green roof include the selection of building and persuading the owners to accept the extensive green roof systems, it is necessary to find an appropriate one in the process of building selection to make extensive green roof systems function well and achieve the best efficiency within the building.

It is necessary to deal with the owners through the whole construction process of the extensive green roof systems. For those owners who are lack of knowledge in extensive green roof systems, they actually do not care about the life cycle cost and are not aware of the benefits of extensive green roof systems. In this context, detail explanation on the operation guidelines and compromise are required.

Since there is no technical standard or specification which has been commonly recognized by the construction industry, great differences are appreciated in line with the qualities of different extensive green roof systems. It is particularly important in Hong Kong. This is due to the difficulties for contractors to prepare specifications to construct extensive green roof systems without standard guidelines. Hong Kong government awards contract to those contractors who submit the lowest tender to construct extensive green roof systems. Quality control may be another problem as low cost always brings about low quality.

Except for these major barriers identified in the questionnaire survey, there are other factors may adversely affect the application as well as the efficiency of extensive green roof systems in Hong Kong existing buildings. They are listed as follows:

- The roof area in many high-rise building is small while lots of building services have been installed;
- The multi-ownership of the roof would make it difficult to apply the extensive green roof systems and make it more difficult to manage if it is applied; and
- The structural capacity of the building may not be suitable for the application of extensive green roof systems

Compared with the low rise buildings such as school and shopping arcades, high-rise buildings usually have more problems in promoting green roof due to the multi-ownership of the roof areas and lots of building services have been installed on the roof. Low rise buildings usually have large area of vacant roof, high accessibility thus more feasible to adopt extensive green roof systems.

6. Conclusion

There are various barriers encountered in promoting extensive green roof systems for the existing buildings in Hong Kong. This study identified the commonly referred barriers. The top three critical barriers encountered in practice are highlighted as 'Lack of promotion from the government and social communities among the public and private sectors', "lack of incentive from the government towards the owners of the existing buildings" and "increase in maintenance cost". Barriers exist in the whole building life cycle process, including plan and design, construction and operation and management stages. This has been evidenced by the three case studies presented in the paper.

Many of these barriers have close correlations with the insufficiency of government policy. In this context, there is an urgent need for the proactive support from the government. It is proposed that relevant policy and regulations on the adoption of extensive green roof systems should be promoted and encouraged by the government. Furthermore, there is a need to stimulate demand for using extensive green roof systems among developers, e.g. by demonstrating the benefits of the system, such as cutting down the maintenance cost. The dissemination of information through the media is recommended to promote extensive green roofs and to foster better understanding of their potential benefits among the public.

Further research is required to find out effective strategies to overcome the major barriers identified in this study. It is expected that the green built environment in these large cities such as Hong Kong can be built with mitigating the barriers in the process of developing extensive green roof systems. This study therefore provides evidence to support the need for solutions to mitigate the barriers of using extensive green roof systems towards contributing to sustainable urban environment.

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